

PLANAR GAP PRE-FILL PROCESS FOR READ HEADS

FIELD OF THE INVENTION

The present invention relates to magnetoresistive read sensors for reading signals
5 recorded in a magnetic medium, and more particularly, this invention relates to improving
gap layers of a magnetoresistive read sensor to optimize operating characteristics.

BACKGROUND OF THE INVENTION

Computer systems generally utilize auxiliary memory storage devices having
media on which data can be written and from which data can be read for later use. A
10 direct access storage device (disk drive) incorporating rotating magnetic disks is
commonly used for storing data in magnetic form on the disk surfaces. Data is recorded
on concentric, radially spaced tracks on the disk surfaces. Magnetic heads including read
sensors are then used to read data from the tracks on the disk surfaces.

In high capacity disk drives, magnetoresistive read sensors, commonly referred to
15 as MR heads, are the prevailing read sensors because of their capability to read data from
a surface of a disk at greater linear densities than thin film inductive heads. An MR
sensor detects a magnetic field through the change in the resistance of its MR sensing
layer (also referred to as an "MR sensor") as a function of the strength and direction of
the magnetic flux being sensed by the MR layer.

20 FIG. 1 illustrates a cross-sectional view of an MR head, in accordance with the
prior art. As shown, an MR read head includes an MR sensor which is sandwiched
between first and second gap layers G1 and G2 which are in turn sandwiched between

first and second shield layers **S1** and **S2**. Lead layers are sandwiched between the first and second gap layers for providing a sense current to the MR sensor. Magnetic fields from a magnetic disk change the resistance of the sensor proportional to the strength of the fields. The change in resistance changes the potential across the MR sensor which is
5 processed by channel circuitry as a readback signal.

An MR read head is typically mounted to a slider which, in turn, is attached to a suspension and actuator of a magnetic disk drive. The slider and edges of the MR sensor and other layers of the read head form an air bearing surface (ABS). When a magnetic disk is rotated by the drive, the slider and one or more heads are supported against the
10 disk by a cushion of air (an "air bearing") between the disk and the ABS. The air bearing is generated by the rotating disk. The read head then reads magnetic flux signals from the rotating disk.

There are two critical dimensions of the MR head, namely the trackwidth and resolution of the MR head. The capability of the MR head to read data recorded at high
15 areal densities is determined by its trackwidth and its resolution.

The trackwidth of the MR read head is the length of the active or sensing region for the MR sensor and is typically defined by the photolithography and subtractive or additive processing. The trackwidth is defined by the recess generated by the photoresist **PR** used during a photolithography process.

20 Resolution, on the other hand, is determined by the gap of the read head which is the distance between the first and second shield layers at the ABS. Accordingly, this distance is the total of the thicknesses of the MR sensor and the first and second gap layers **G1** and **G2**. When the first and second gap layers **G1** and **G2**, which separate

the MR sensor from the first and second shield layers **S1** and **S2**, become thinner, the linear resolution of read head becomes higher. A serious limitation on the thinness of the gap layers of the read head is the potential for electrical shorting between the lead layers and the first and second shield layers. The thinner a gap layer, the more likely it is to have
5 one or more pinholes which expose a lead layer to a shield layer. Pinholes can significantly reduce the yield of a production run of MR read heads.

It is important to note that the only place where the gap layers have to be thin is in an MR region where the MR sensor is located. The gap layers can be thicker between the lead layers and the first and second shield layers. Accordingly, it is desirable if each gap
10 layer could be thin in the MR region to provide high linear resolution and thick outside of the MR region to provide good insulation between the lead layers and the shield layers.

The MR read head of FIG. 1 accomplishes this using a two step process of depositing first gap layers before the MR sensor is deposited and a two step process of depositing second gap layers after the MR sensor is deposited. In the present device, a
15 very thin first gap layer **G1** is deposited on the first shield layer **S1**. An MR region is then masked and a first gap pre-fill layer **G1P**, which may be thicker than **G1**, is deposited. The mask is removed, leaving the first gap pre-fill layer **G1P** everywhere except in the MR region. Lead layers **L1** and **L2** and an MR sensor are then formed.

Next, a very thin second gap layer **G2** is deposited. The MR region is then
20 masked and a second gap pre-fill layer **G2P** is deposited. After lifting off the mask, the **G2P** layer is located everywhere except in the MR region. The result is that very thin **G1** and **G2** layers are in the MR region at the bottom and top of the MR sensor to provide the MR head with a high linear resolution, the **G1** and **G1P** layers are located between the

leads and the first shield layer **S1** to prevent shorting between the lead layers and the first shield layer **S1**, and the **G2** and **G2P** layers are located between the lead layers and the second shield layer **S2** to prevent shorting between the lead layers and the second shield layer **S2**.

5 As such, the present device is capable of providing a read head which has a very thin gap layer at the MR region, and yet will prevent shorts between lead layers and the first and second shield layers.

 Despite this, the MR read head of FIG. 1 includes gap layers **G1**, **G1P**, **G2**, and **G2P** which afford many non-planar surfaces in the form of beveled edges
10 circumnavigating the MR sensor. Such non-planar surface must, in turn, be subjected to photoresist layers during processing. Due to inherent limitations of photolithography, two problems result which compromise control of the critical trackwidth and resolution dimensions.

 First, the beveled edges cause reflective notching due to light scattering. See
15 arrows in FIG. 1. Secondly, the non-planar surfaces cause non-uniform photoresist coverage during processing which, in turn, invokes the well known "swing curve" effect. FIG. 2 illustrates the manner in which the critical dimensions (trackwidth and resolution) vary as a function of photoresist thickness, in accordance with the swing curve effect. As is well known, the constructive and destructive interference of reflected light within the
20 photoresist film causes the swing curve effect.

 Prior art devices have attempted to overcome the foregoing disadvantages through the addition of antireflective layers and planarization. Unfortunately, antireflective layers are only partially effective and introduce complications associated with their removal.

There is therefore a need for an MR read head with an improved gap layer which utilizes planar surfaces to avoid adversely affecting the MR region, while providing a thin gap layer adjacent to the MR region and a thick gap layer between lead layers and the first and second shield layers.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to disclose a magnetoresistive (MR) read head with an improved gap layer which does not adversely affect the MR region.

It is another object of the present invention to disclose an MR read head which
5 has a very thin gap layer adjacent to the MR region.

It is still another object of the present invention to disclose an MR read head which has a very thick gap layer between lead layers and the first and second shield layers of the MR read head.

It is still yet another object of the present invention to disclose an MR read head
10 which has gap layers that are planar to avoid the negative ramifications of reflective notching and the swing effect.

These and other objects and advantages are attained in accordance with the principles of the present invention by disclosing an MR read head including a shield layer with a recessed portion and a protruding portion defined by the recessed portion. Also
15 included is an MR sensor located in vertical alignment with the protruding portion of the shield layer. Further provided is at least one gap layer situated above and below the MR sensor. At least one of such gap layers is positioned in the recessed portion of the shield layer.

In one embodiment of the present invention, the gap layers may include a first gap
20 layer located on top of the recessed portion of the shield layer. Such first gap layer may include an upper surface substantially level with an upper surface of the protruding portion of the shield layer. As an option, the recessed portion of the shield layer may be formed by an etching process.

The gap layers may further include a second gap layer located on top of the first gap layer and the protruding portion of the shield layer. The MR sensor may be located on top of the second gap layer. As a result of the aforementioned underlying structure, an upper surface of such second gap layer may be planar to avoid the negative ramifications of reflective notching and the swing effect.

In addition to the first and second gap layers, a third gap layer may be located on top of the MR sensor.

To this end, a combined thickness of the first gap layer, second gap layer, and third gap layer is thinner adjacent to the MR sensor and the protruding portion of the shield layer than the recessed portion of the shield layer for insulation purposes.

In yet another embodiment, a method is provided for fabricating the MR read head. Initially, a shield layer is deposited. Thereafter, a recessed portion is etched in an upper surface of the shield layer. Such recessed portion of the shield layer defines a protruding portion of the shield layer. A first gap layer is deposited on top of the recessed portion of the shield layer, and a second gap layer is deposited on top of the first gap layer and the protruding portion of the shield layer. Next, an MR sensor is positioned on top of the second gap layer in vertical alignment with the protruding portion of the shield layer. First and second lead layers are subsequently positioned on top of the second gap layer. The first and second lead layers are positioned such that they are connected to the MR sensor. A third gap layer is then deposited on top of the second gap layer, the MR sensor, and the first and second lead layers.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

5 FIG. 1 illustrates a cross-sectional view of a (magnetoresistive) MR head, in accordance with the prior art.

FIG. 2 illustrates the manner in which the critical dimensions vary as a function of photoresist thickness, in accordance with the swing curve effect.

FIG. 3 is a perspective drawing of a magnetic recording disk drive system.

10 FIG. 4 illustrates an MR read head constructed in accordance with one embodiment of the present invention.

FIG. 5 illustrates a plan cross-sectional view of the MR read head taken along line 5-5 shown in FIG. 4.

FIG. 6 illustrates a method for fabricating the MR read head of FIGs. 4 and 5.

15 FIGs. 7A-7I illustrate the MR read head during the various stages of fabrication in accordance with FIG. 6.

BEST MODE FOR CARRYING OUT THE INVENTION

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating
5 the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. 3, there is shown a disk drive 300 embodying the present invention. As shown in FIG. 3, at least one rotatable magnetic disk 312 is supported on a spindle 314 and rotated by a disk drive motor 318. The magnetic recording media on each
10 disk is in the form of an annular pattern of concentric data tracks (not shown) on disk 312.

At least one slider 313 is positioned on the disk 312, each slider 313 supporting one or more magnetic read/write heads 321 where the head 321 incorporates the MR sensor of the present invention. As the disks rotate, slider 313 is moved radially in and
15 out over disk surface 322 so that heads 321 may access different portions of the disk where desired data are recorded. Each slider 313 is attached to an actuator arm 319 by way of a suspension 315. The suspension 315 provides a slight spring force which biases slider 313 against the disk surface 322. Each actuator arm 319 is attached to an actuator 327. The actuator 327 as shown in FIG. 3 may be a voice coil motor (VCM). The VCM
20 comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller 329.

During operation of the disk storage system, the rotation of disk 312 generates an air bearing between slider 313 and disk surface 322 which exerts an upward force or lift

on the slider. The air bearing thus counter-balances the slight spring force of suspension 315 and supports slider 313 off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit 329, such as access control signals and internal clock signals. Typically, control unit 329 comprises logic control circuits, storage and a microprocessor. The control unit 329 generates control signals to control various system operations such as drive motor control signals on line 323 and head position and seek control signals on line 328. The control signals on line 328 provide the desired current profiles to optimally move and position slider 313 to the desired data track on disk 312. Read and write signals are communicated to and from read/write heads 321 by way of recording channel 325.

The above description of a magnetic disk storage system of the present invention, and the accompanying illustration of FIG. 3 are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. 4 illustrates an MR read head 400 constructed in accordance with one embodiment of the present invention. As shown, the MR read head 400 includes a shield layer S1 with a recessed portion 402 and a protruding portion 404 defined by the recessed portion 402. In one embodiment, the recessed portion 402 of the shield layer S1 is formed by any desired etching process. In particular, ion milling, reactive ion etching, wet etching, etc. may be utilized.

Next provided is a first gap layer **G1** located on top of the recessed portion **402** of the shield layer **S1**. The first gap layer **G1** includes an upper surface **405** substantially level with an upper surface **406** of the protruding portion **404** of the shield layer **S1**. The first gap layer **G1** and the remaining gap layers may be constructed utilizing alumina, aluminum oxide, or any other desired insulating material. Moreover, such gap layers may be deposited utilizing any desired process such as sputtering or the like.

As an option, the upper surface **405** of the first gap layer **G1** may reside slightly below the upper surface **406** of the protruding portion **404** of the shield layer **S1**. In such embodiment, a chemical-mechanical polishing process or the like may be utilized to achieve planarity. It is preferred that the upper surface **405** of the first gap layer **G1** be planar and level with the upper surface **406** of the protruding portion **404** in order to avoid reflective notching and the swing curve effect.

With continuing reference to FIG. 4, a second gap layer **G2** is shown to be located on top of the first gap layer **G1** and the protruding portion **404** of the shield layer **S1**. Similar to the upper surface **405** of the first gap layer **G1**, it is preferred that an upper surface **410** of the second gap layer **G2** is planar.

Located on top of the second gap layer **G2** is an MR sensor that is positioned in vertical alignment with the protruding portion **404** of the shield layer **S1**. In one embodiment, the size and shape of the protruding portion **404** of the shield layer **S1** is similar to that of the MR sensor. Preferably, the size of the protruding portion **404** of the shield layer **S1** is slightly larger than that of the MR sensor. The MR sensor may be constructed utilizing Permalloy (nickel iron) or any other desired material. Moreover, the

MR sensor may be deposited utilizing any desired process such as sputtering, vacuum deposition, plating or the like.

Also located on top of the second gap layer **G2** are first and second lead layers which are connected to the MR sensor. The first and second lead layers may be
5 constructed utilizing copper or any other conductive material. Similar to the MR sensor, the first and second lead layers may be deposited utilizing any desired process such as sputtering, vacuum deposition, plating or the like.

A third gap layer **G3** is located on top of the MR sensor, the first and second lead layers, and the second gap layer **G2**. While not shown, it should be noted that another
10 shield layer **S2** and other layers may be deposited on top of the third gap layer **G3**, as is well known to those of ordinary skill. In use, the gap layers provide insulation between the lead layers and the shield layers **S1** and **S2**.

By this design, a combined thickness of the first gap layer **G1**, second gap layer **G2**, and third gap layer **G3** is thinner adjacent to the MR sensor and the protruding
15 portion **404** of the shield layer **S1** than the recessed portion **402** of the shield layer **S1**. As such, the lead layers enjoy the increased combined thickness of the gap layers. This is important to reduce the chance of a short occurring between the lead layers and shield layers **S1** and **S2**.

Moreover, beveled edges and nonplanarity are avoided by maintaining planar gap
20 layer surfaces through use of the recessed portion **402** of the shield layer **S1**. To this end, the detrimental ramifications of reflective notching and the swing curve effect are avoided.

FIG. 5 illustrates a plan cross-sectional view of the MR read head **400** taken along line **5-5** shown in FIG. 4. As shown, the protruding portion **404** of the shield layer **S1** defines the recessed portion **402** in which the first gap layer **G1** resides.

FIG. 6 illustrates a method **600** for fabricating the MR read head **400** of FIGs. 4 and 5. Initially, in operation **602**, the shield layer **S1** is deposited on a substrate. Thereafter, in operation **604**, the recessed portion **402** is etched in an upper surface of the shield layer **S1**. Such recessed portion **402** of the shield layer **S1** defines the protruding portion **404** of the shield layer **S1**. The recessed portion **402** of the shield layer **S1** is preferably of a predetermined depth that effectively provides the desired amount of insulation.

Subsequently, the first gap layer **G1** is deposited on top of the recessed portion **402** of the shield layer **S1**. Note operation **606**. As an option, a chemical-mechanical polishing process may be carried out on the upper surfaces of the first gap layer **G1** and the recessed portion **402** of the shield layer **S1**. Such chemical-mechanical polishing process serves to remove any residual nonplanarity around the protruding portion **404** of the shield layer **S1**.

In operation **608**, the second gap layer **G2** is deposited on top of the first gap layer **G1** and the protruding portion **404** of the shield layer **S1**. Next, in operation **610**, the MR sensor is positioned on top of the second gap layer **G2** in vertical alignment with the protruding portion **404** of the shield layer **S1**.

First and second lead layers are subsequently positioned on top of the second gap layer **G2**. Note operation **612**. The first and second lead layers are positioned such that they are connected to the MR sensor. The third gap layer **G3** is then deposited on the

second gap layer **G2**, the MR sensor, and the first and second lead layers, as indicated in operation **614**. While not shown, another shield layer **S2** may be deposited on top of the third gap layer **G3** in addition to any remaining layers that are well known to those of ordinary skill.

5 It should be understood that the order of operations in the method **600** of fabrication may vary per the desires of the user. For example, the shield layer **S1** and first gap layer **G1** may both be deposited before the patterning and etching processes are carried out to form the recessed portion **402** of the shield layer **S1**. Thereafter, the second gap layer **G2** and the MR sensor may be deposited. While this and other variations are
10 possible, the method **600** of fabrication is preferred since the MR sensor is deposited on a more pristine surface.

FIGs. **7A-7I** illustrate the MR read head during the various stages of fabrication in accordance with FIG. **6**. As shown in FIG. **7A**, the shield layer **S1** is deposited in accordance with operation **602** of FIG. **6**. FIG. **7B** illustrates the manner in which
15 photoresist **PR** is deposited in preparation for etching the recessed portion **402** of the shield layer **S1** in operation **604** of FIG. **6**. FIG. **7C** illustrates the results of the etching in accordance with operation **604** of FIG. **6**.

FIG. **7D** shows how the first gap layer **G1** is deposited on top of the recessed portion **402** of the shield layer **S1**. Note operation **606** of FIG. **6**. FIG. **7E** illustrates the
20 manner in which the photoresist **PR** is removed after operation **606** of FIG. **6**. The second gap layer **G2** is deposited on top of the first gap layer **G1** and the protruding portion **404** of the shield layer **S1** in accordance with operation **608** of FIG. **6**, as shown in FIG. **7F**.

Next, the MR sensor is positioned on top of the second gap layer **G2** in vertical alignment with the protruding portion **404** of the shield layer **S1** in accordance with operation **610** of FIG. 6. Note FIG. **7G**. FIG. **7G** also shows additional photoresist **PR** that is deposited in anticipation of etching the MR sensor layer so that lead layers may be deposited over the second gap layer **G2** in accordance with operation **612** of FIG. 6. Note FIG. **7H**. As shown in such Figures, the MR sensor and lead layers are planar as a result of being deposited on the planar first gap layer **G1** and planar second gap layer **G2**. This planarity enables the advantages of the present invention.

FIG. **7I** shows the manner in which the third gap layer **G3** is deposited in accordance with operation **614** of FIG. 6. It should be noted that a second shield layer **S2** may subsequently be deposited as well.

To this end, the combined thickness of the gap layers is increased to reduce the chance of a short occurring between the lead layers and shield layers **S1** and **S2**. Further, beveled edges and nonplanarity are avoided by maintaining planar gap layer surfaces. To this end, the detrimental ramifications of reflective notching and the swing curve effect are avoided.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.